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Synthetic liquid fuels: prospects for innovative technologies based on underground coal gasification

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Abstract. The growing demand for energy, the depletion of oil and gas reserves, and the threat of global climate change have led to an increase in interest in underground coal gasification technologies (UCG) around the world. The potential for using underground gasification of low-grade coal resources with complex mining and geological conditions is huge. The main challenge is the development of competitive technologies for the production of synthesis gas and production of electricity, heat, and synthetic liquid fuels on its basis.

The paper presents a study of one of the promising areas of the use of UCG gas for the combined production of synthetic liquid fuel (methanol) and electricity. A mathematical model of the installation for combined production of methanol and electricity (ICPME) was developed. Based on this mathematical model, a technical and economic optimization of the parameters was carried out to assess the prospects of the scale of application of this coal processing method.

The purpose of research conducted using the mathematical models of the ICPME is to determine the optimal parameters of the installation and the sensitivity of its economic performance indicators to changes in external conditions.

Introduction

The growing demand for energy, the depletion of oil and gas reserves, and the threat of global climate change leads to an increase in interest in underground coal gasification technologies (UCG) around the world. The potential for using underground gasification of low-grade coal resources with complex mining and geological conditions is huge. The main challenge is the development of competitive technologies for the production of synthesis gas and production of electricity, heat, and synthetic liquid fuels on its basis.

The paper considers an upcoming trend in processing of UCG gas enriched with hydrogen and carbon oxides. Pre-purified gas can be considered as synthesis gas for production of valuable synthetic liquid fuels (SLF). Of SLFs, we consider, first of all, methyl alcohol, an environmentally friendly energy carrier that can be used not only as a power-generating fuel but also as a motor fuel [1-7].

Methanol has been one of the most widely used industrial chemicals in the world since the 1800s. It is a key component of hundreds of chemicals. The most large-scale applications in terms of volume are its processing into formaldehyde, which is additionally processed to form resins, adhesives, and various plastics, as well as to produce acetic acid (Fig. 1). Worldwide, one-third of the methanol demand is for formaldehyde production. This accounts for about 10 million metric tons, which is the largest methanol market. One of the newest and fastest growing markets for methanol is the production of light olefins. Olefins, i.e. ethylene and propylene, serve as the backbone of the plastics industry and are usually produced by steam cracking of hydrocarbons such as ethane and naphtha.

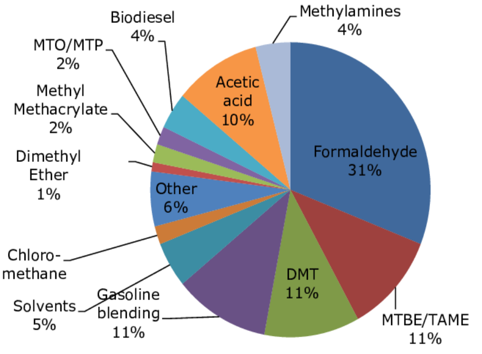

Fig. 1. The uses of methanol (https://www.methanol.org).

A new trend, that of the use of methanol as an environmentally friendly fuel for electricity generation, is gaining momentum. There are several projects worldwide to incorporate methanol into existing gas dual-fueled turbines using. Methanol's low calorific value, low lubricity, and low flash point make it an excellent turbine fuel compared to natural gas and distillate, which can lead to lower emissions, improved heat rate, and higher

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power output. A recent methanol-to-power demonstration project by General Electric has shown the viability of this technology, especially for areas not close to gas pipelines.

In the present study, the synthesis gas of UCG of the Rakovsky lignite deposit of the Far East is used for methanol production. The Rakovskoe lignite deposit is located in an area reclaimed by the coal industry with a developed infrastructure and energy consumers available.

According to studies performed by the A. A. Skochinsky Institute of Mining, established reserves of coal by various formations deposited below the strip-mining line and suitable for underground gasification, are 69.2 million tons of category C and 17.6 million tons of category C2, which ensures the operation of the station "Podzemgaz" for its service life at any capacity**.** Novel designs of underground gas generators and technological solutions allow to enhance the characteristics of produced gas and the efficiency of the gasification process [8-11].

Compared to conventional mining and surface gasification, UCG promises lower capital/operating costs as well as other benefits such as no human labor underground. In addition, UCG can potentially be associated with carbon dioxide capture and absorption [12, 13].

The paper presents a study of one of the promising areas of the use of UCG gas for the combined production of SLF (methanol) and electricity.

The processing of UCG gas into methanol is characterized by the release of large amounts of heat and carbon oxides. Combination of chemical processes with power generation increases efficiency of UCG gases utilization. The analytical study of technologies for processing various organic raw materials, performed at the Melentiev Energy Systems Institute Siberian Branch of the Russian Academy of Sciences (ESI SB RAS), revealed the expediency of combining chemical processing technology with power generation in installations for combined production of methanol and electricity (ICPME). The energy and economic efficiency of such an integrated process is much higher than that of separate production processes [7, 14, 15].

A mathematical model of the installation for combined production of methanol and electricity (ICPME) was developed. Based on this mathematical model, a technical and economic optimization of the parameters was carried out to assess the prospects of the scale of application of this method of utilizing UCG gas.

It proves feasible to build small power engineering units for processing of UCG gas. In this case, the power of the ICPME can be increased by units connected in series as needed.

Below is presented a study of the ICPME operating on the products of underground coal gasification under the conditions specific to Far East. The performed research focused on optimizing the operation of the synthesis unit and power generation unit. The data on the method of gasification, composition, and specification of UCG gas of the Rakovsky deposit were obtained from the Far Eastern State Technical University through the courtesy of the team of researchers under the supervision of Professor B.I. Kondyrev [16, 17].

1 The current state of research in the field

As was noted, at present in Russia and abroad there are ongoing studies on deep processing of solid fuels by the underground gasification method, which is one of the key directions of the introduction of additional volumes of energy resources into fuel and energy balances [18].

The analysis of the activity of domestic industrial UCG enterprises with respect to the production of the gaseous energy carrier of low heat of combustion (up to 4 MJ/m^3) attests to their technical and economic feasibility if compared to shaft mining of coal [19**].**

In articles [8-9, 16, 17] the authors analyzed the development of technologies for underground gasification of coal and presented the prospects of development of coal deposits in the Far East.

Studies [11, 20] demonstrated that the attained technological level of development of the UCG process allows producing gas with sufficiently stable qualitative and quantitative parameters depending on the applied process tools and requirements on the part of consumers.

The study [17] traced the history of development of the technology of underground coal gasification in Russia and abroad. The authors covered the key strands of UCG technology improvement that are undergoing development at the Far Eastern State Technical University, where the center for deep processing of coal is being established. The important role of the described technology was emphasized, and information on UCG plants under construction in the Far East region was presented.

Studies [21-24] analyzed the energy efficiency of the complete process cycle from coal mining to coal use at combined heat and power plants. Innovative solutions for increasing energy efficiency and energy saving of hydrocarbon resources, based on building local coal and gas energy complexes, were proposed. The estimates of the degree of an increase in combustion heat of the generating mixture so as to achieve the level required for gas-turbine generating units was provided.

Articles [25-28] reported on research on UCG with the main emphasis on chemical and physical characteristics of feedstock, process chemistry, gasifier design, and operating conditions. Thermodynamic studies of UCG were also presented with an emphasis on optimization of gas generator operation based on thermodynamics and kinetic models of the process built.

Study [29] presented an overview of fundamental physical phenomena in underground coal gasification and related modeling challenges. Transfer phenomena and chemical reactions occurring in a permeable layer of coal and ash as well as in the hollow space were considered. Modelling of heat and mass transfer, including pollutants, in the near and far fields surrounding the underground coal gasifier was carried out. Integrated UCG models were considered and recommendations for further model development were provided.

Experimental studies are carried out, aimed at obtaining well-grounded results on UCG [17, 30], including obtaining optimal compositions of gasifying agents, which plays an important role in the economy of underground coal gasification.

As it can be seen from the review, most of the research on technologies behind producing electricity, heat, and SLF from UCG gas worldwide and in Russia alike deal with the study of individual processes and devices. In comprehensive studies of technologies of electricity and heat production and SLF synthesis, for the most part it is the thermodynamic efficiency analysis that is carried out. Optimization studies of such complex combined systems as power engineering installations of combined production of SLF and electric power, using detailed models of power and engineering elements taking into account non-linearity of processes, have not been carried out. On the other hand, without such an analysis it is impossible to obtain optimal technical solutions and sufficiently unbiased economic performance indicators that determine the conditions of competitiveness of the technologies that are studied. Therefore, taking into account these circumstances is one of the main objectives of the present study.

2 A concise overview of the method of underground coal gasification and the use of gas for methanol production

A state-of-the-art underground gas generator engineered by Gazprom Promgaz was selected for the pilot industrial UCG enterprise at the Rakovsky brown coal deposit. The novel UCG process implements a directed oxidizer supply to the hot reaction surface of the coal seam, which provides a higher temperature level and CO discharge. In addition, the sustainability and stability of the gas formation process is due to the movement (as the coal seam is extracted) of the reaction channel of constant geometric parameters [16, 17]. The pilot industrial gas generator includes a series of parallel directional gas exhaust and injection wells, which are crossed on the horizon of the initial gasification channel by a horizontal directional well. The transfer of the air supply point to the coal seam reaction zone (from bottom to top) is provided for as the coal seam is extracted. A schematic of the presented technology of using UCG gas is shown in Fig. 2.

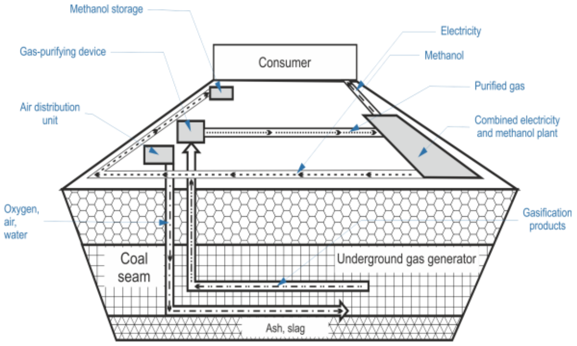


Fig. 2. Schematic of energy resources production complex based on UCG gas.

The new CCGT technology provides higher sustainability and stability of the gas generation process, higher efficiency of gasification, reduction of the number and volume of production wells drilling, the possibility of controlling the process of thermal reactions inside the seam.

The UCG gas deemed optimal for the synthesis of methanol gas is characterized by a sufficiently high H_2/CO ratio and calorific value.

3 Production of methanol and electricity from UCG gas

Below is presented a study of the ICPME operating on the products of underground coal gasification under the conditions specific to Far East. The process flow diagram of the installation is shown in Fig. 3.

The synthesis gas coming from the underground coal gasification station is compressed by fresh gas compressors (1) to a pressure of 2.7 MPa. The gas is then successively heated in a regenerative heater (2) to 340^0 C and an end electric heater (3) to 350^0 C. Heated gas is directed to the desulfurization reactor (4) where hydrogen sulfide is absorbed. From the reactor the purified gas passes through a regenerative heat exchanger and compressor cooler (24) where it is cooled. The gas is then compressed by the compressor to a pressure of 8 MPa and supplied to the methanol synthesis unit. The synthesis unit includes three stages. Each stage has a methyl alcohol synthesis reactor (5), regenerative heat exchanger (6), cooler/condenser of crude methanol (7), and separator (8). The gas is heated in a regenerative heat exchanger up to 210^0 C, then it enters an isothermal synthesis reactor, where a process of methanol formation takes place with a copper-zink-aluminum catalyst at 260^0 C. The heat generated there is used to produce steam at a pressure of 4.3 MPa. Downstream of the reactor, the gas is directed to a regenerative heat exchanger and a cooler/condenser, where it is cooled down to 30^0 C. This condenses methyl alcohol and water vapors. The separator separates the condensate from the gas. The gas passes sequentially through three stages of the synthesis unit.

From the third stage, the purging gas enters the expansion gas turbine (9), where its pressure is reduced to 1.0 MPa. The gas is cooled by the coolant in the heat exchanger (10). The heat dissipation is 140 kcal/s. The coolant can be used in a gas treatment system or for other purposes. The gas downstream of the heat exchanger is directed to the combustion chamber (11) of the main gas turbine (12). The air from the compressor is also supplied there (13).

The main and expansion gas turbines, air compressor, and electric generator are located on the same shaft. After the gas turbine, the combustion products are fed into the recovery boiler that includes five heating surfaces: low- (14) and high- (16) pressure economizers, low- (15) and high- (17) pressure vaporizers, and a steam superheater (18). The high- and low-pressure steam generated in the recovery boiler from the separator drums (19) is directed to the steam turbine (20).

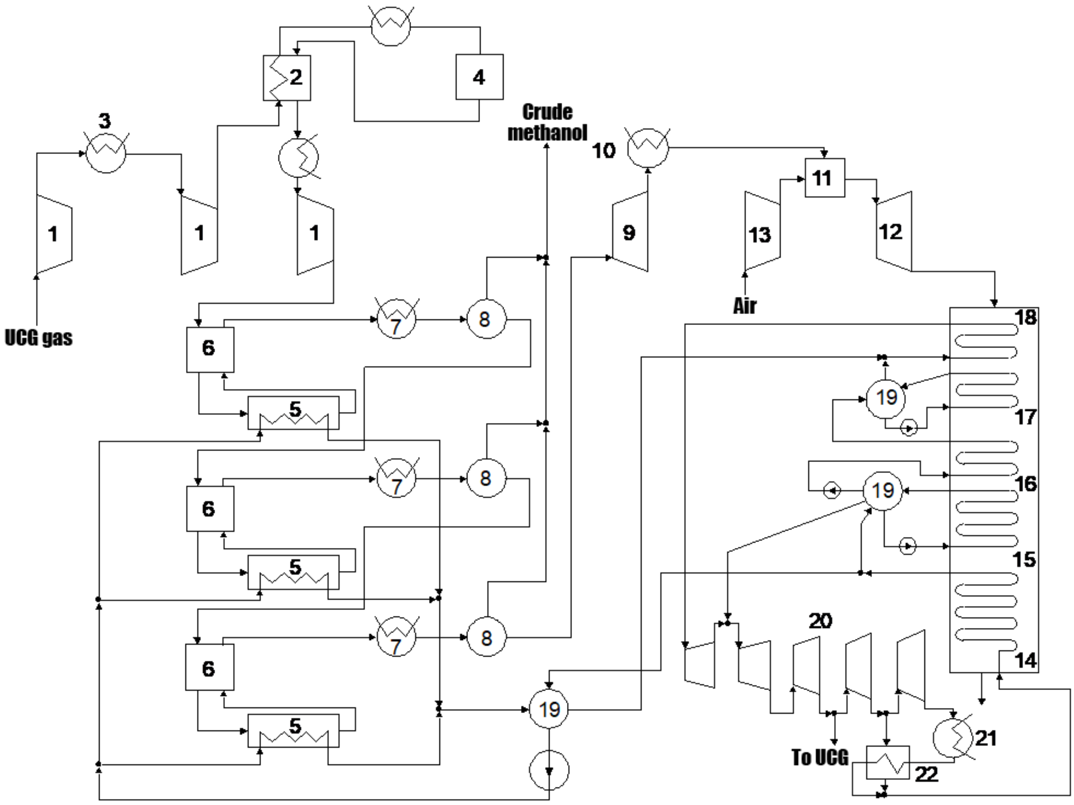


Fig.3. Process flow diagram of the ICPME

From the turbine, steam is supplied into the condenser (21). Feedwater is heated in a regenerative heater (22). From the steam turbine, Steam is extracted from the steam turbine for underground coal gasification.

4 Mathematical modeling of ICPME

Models of individual energy and technological elements (methanol synthesis) were used in the development of a mathematical model of the installation as a whole: heat exchangers of various types, combustion chambers, compressors, gas and steam turbines, built-in gas-water, regenerative gas-gas heat exchangers of a methanol synthesis reactor, refrigerators-condensers, methanol separators, etc.). The issues of modeling energy and technological elements are considered in the previously published works of ESI SB RAS [31-34].

A catalytic reactor for the synthesis of methanol is a fundamentally new element that is absent in power plants. The state of the gas mixture in the reactor differs significantly from the equilibrium state and is described by differential equations of chemical kinetics. The mathematical model of the reactor is based on the methyl alcohol synthesis mechanism and kinetic equations developed at A.V. Topchiev Institute of Petrochemical Synthesis of Russian Academy of Sciences [35-37]. The methanol synthesis reactor consists of several adiabatic zones filled with a catalyst, between which convective heat exchangers are located to recover the heat of synthesis. To simplify calculations, the zones are divided into sections.

The following conditions were taken into account when developing an algorithm for solving the system of equations for a reactor section. The rates of CH_3OH and CO formation are determined by the equilibrium and rate constants, which are uniquely dependent on the gas temperature, pressure, and molar fractions of the components of the gas mixture. The change in pressure, as well as in the equilibrium and rate constants in the working range of the synthesis process is small. The change in the mole fractions of individual components is very significant. In addition, their effect on the rates of CH_3OH and CO formation is significant. Therefore, the pressure of the gas mixture, the rate constants and equilibrium constants can be considered constant in much larger sections of the adiabatic zone of the reactor than the mole fractions of the components (we will call the first sections large, and the second small). This allows you to significantly reduce the amount of calculations when calculating the adiabatic zone.

For the numerical integration of the system of equations describing the processes in a small section of the reactor, the fourth-order Runge-Kutta method is used. The component-wise molar flow rates, gas temperature and pressure at the outlet from the adiabatic zone are determined from expressions corresponding to the integration of differential equations by the Euler method.

The investigated installation is a difficult combined technical system with a large number of dissimilar elements connected by various technological connections. The software and computer complex developed at ESI SB RAS - the system of machine construction of programs (SMPP-PC) - was used to construct a mathematical model. Based on the information about the mathematical models of the individual elements of the installation, the technological connections between them and the purposes of the calculation, the SMPP-PC automatically generates a mathematical model in the form of a calculation program in the Fortran language [14, 31]. This model corresponds to the design scheme shown in Figure 3. The calculation program contains about 1500 variables, several hundred algebraic and transcendental equations. The solution of the systems of equations describing the entire installation is carried out by the Zeidel method [32].

On the basis of the mathematical model of ICPME, the design calculation of the installation elements is carried out: determination of the heating surfaces of heat exchangers and the mass of metal, the volume of the catalyst in the reactors, the drive power of pumps and compressors, the power of gas and steam turbines, thermodynamic parameters, the consumption of synthesis gas, combustion products, water and steam at various points in the circuit.

5 Research the ICPME

The purpose of studies backed by mathematical models of the ICPME that make use of UCG gas is to determine optimal parameters of the installation and sensitivity of its economic performance indicators to changes in external conditions, first of all, the cost of gas of underground coal gasification. This is required in order to assess the prospects of applying this method to using UCG gas.

Problem statement for ICPME parameters optimization

$$\min_{dl} c_{UCG}(x,y,dl,V_{cat},G_{ms},G_{lps},B_{UCG},KI,P_{meth},P_{el},c_{meth},c_{el},IRR_z),$$

given that

$$H(x,y)=0,$$

$$G(x,y)=0,$$

$$x_{min} \le x \le x_{max},$$

$$T_{sg} \ge T_{cat},$$

$$IRR = IRR_z,$$

where c_{UCG} is a price of gas UCG, x is a vector of independent optimized parameters; y is a vector of dependent calculated parameters; H is a vector of constraint equalities (constraints on material balances, energy balances, heat transfer, etc.); G is a vector of constraint inequalities; $x_{\min}$, $x_{\max}$ are a vectors of boundary values of optimized parameters; dl - length of the synthesis reactor; V_{cat} - volume of catalyst in synthesis reactors; G_{mg} - main steam consumption; G_{lps} - low pressure steam consumption; B_{UCG} - annual gas UCG consumption; KI - investment in ICPME; P_{el} - annual electricity production; P_{meth} - annual methanol production; c_{meth} - methanol price; c_{el} - produced electricity price; IRR_z is a predefined internal rate of return on capital investment, T_{sg} - the temperature of the synthesis gas in the synthesis reactors, T_{cat} - the maximum permissible temperature of the synthesis gas according to the operating conditions of the catalyst.

The parameters to be optimized were the enthalpies, pressures and flow rates of main, high- and low- pressure steam in the power generation unit, the volume of catalyst in the sections of the synthesis reactor, etc. The system of restrictions contains the conditions for non-negativity of the end temperature drops of heat exchangers, pressure drops along the flow path of steam and gas turbines, restrictions on the design temperatures and mechanical stresses of heat exchanger pipes, on the minimum and maximum synthesis temperatures, etc.

Input technical and economic data was assumed on the basis of previous studies carried out at the ESI SB RAS that dealt with the subject of technologies of solid fuel processing into SLF and on the basis of an analysis of cost estimates of process and power facilities taking into account ICMPE operating conditions [7, 14, 15, 31-34].

Input data for calculations of the ICPME.

Table 1 shows the main input data that was used to determine the technical and economic performance indicators of the ICPME. The capital costs calculations were based on the unit costs of equipment presented in the table, with the unit cost increase due to its small scale being taken into account by a cost factor of 1.5.

Table 1. Input data for ICPME calculations

Name	Unit	Value
1	2	3
Synthesis process pressure	*MPa*	8
Gas temperature at the inlet of synthesis reactors	*K*	493.15
Gas temperature at the outlet of synthesis reactors	*K*	543.15
Gas temperature downstream of coolers/condensers	*K*	303.15
Gas temperature upstream of the main gas turbine	*K*	1373.15
Gas pressure upstream of the main gas turbine	*MPa*	0.96
Main steam pressure	*MPa*	13
Main steam enthalpy	*kcal/kg*	800
Superheated steam pressure	*MPa*	2.1
Superheated steam enthalpy	*kcal/kg*	800
Steam pressure in low pressure vaporizing circuit	*MPa*	1.2
Catalyst unit cost	*USD/kg*	25
Gas turbine unit cost	*USD/kW*	700
Unit cost of a synthesis gas compressor	*USD/kW*	200
Air compressor unit cost	*USD/kW*	150

End of the table 1

1	2	3
Unit cost of heating surfaces made of low-alloy steel	*USD/m²*	1800
Unit cost of heating surfaces made of carbon steel	*USD/m²*	1350
Unit cost of synthesis unit housings	*thous. USD doll./m*	180
Unit cost of process water supply system channels	*thous. USD/(t/h)*	120
Unit cost of process water supply system coolers	*thous. USD /MW*	50
The share of costs for construction and installation work of the synthesis unit		0.6
The share of costs for construction and installation work of the power unit		1
Percentage of depreciation charges	*%*	3.5
Percentage of expenses for running and major repairs	*%*	4.5
Deposit interest rate	*%*	6
Loan interest rate	*%*	7
Plant operation period	*years*	30
Installation construction time	*years*	3

Annual fresh gas consumption is 250 million nm^3 (29.8 nm^3 /hour, 8.27 nm^3/sec), operating hours of the unit per year are 8.400.

The underground coal gasification gas composition at the ICPME inlet (after pre-treatment) is presented below.

Gas components, vol. %:

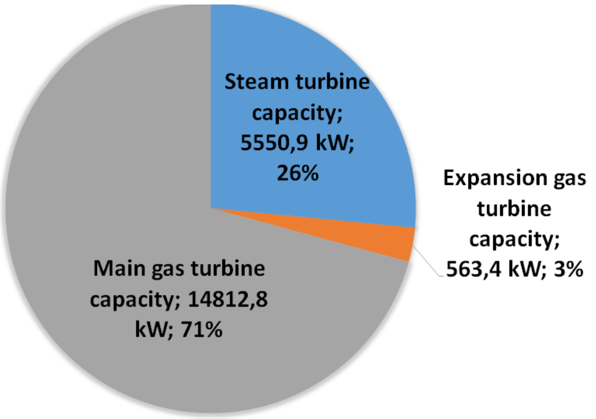
- Carbon dioxide, 6.2
- Hydrogen, 41
- Carbon oxide, 31.4
- Nitrogen oxides, 16.7
- Methane, 1.4
- Water, 3
- Oxygen, 0.2
- Sulfur oxides, 0.01
- Ammonia, 0.01
- Tar, 0.05

As a result of calculations performed with the aid of the mathematical model of the ICPME, we determined the structural characteristics of the main elements of the plant (volume of catalyst in the reactor, areas of heat exchanger heating surfaces, etc.), parameters of material and energy flows between the elements of the scheme, as well as methanol and electricity production. Based on these data, the capital investment in the plant and current costs were estimated.

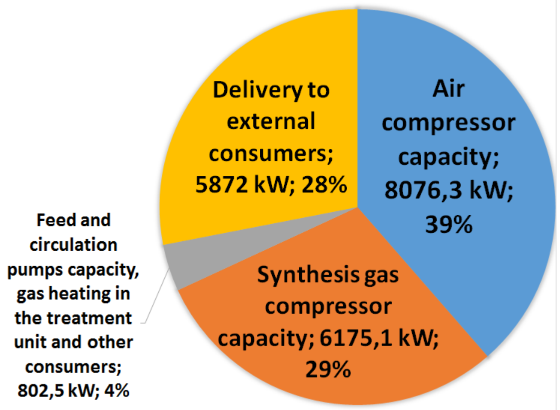
The results of the calculations are given in Tables 2-3, Figure 4 below. Gas composition at the outlet of the synthesis unit is presented below.

Gas components, vol. %:

- Carbon dioxide, 14.4
- Hydrogen, 16.4
- Carbon oxide, 29.2
- Nitrogen oxides, 36.5
- Methane, 3.1
- Water, 0.08
- Methanol, 0.4



a) Output.



b) Consumption and delivery to external consumers

Fig. 4 a, b. Power balance of the UCG ICPME.

Table 2. Synthesis unit equipment specification

Name	Stage 1	Stage 2	Stage 3	Total
Catalyst weight, *t*	9	3.9	2.6	15.5
Reactor volume, *m²*	20.9	9.2	6.3	36.4
Reactor height, *m*	7	7	7	
Reactor diameter, *m*	2	1.3	1	
Regenerative heater heating surface area, *m²*	26.4	32.5	32	90.9
Regenerative heater weight, *t*	0.21	0.26	0.26	0.73
Regenerative heater length, *m*	14.7	21.9	23.9	
Regenerative heater diameter, *m*	0.18	0.17	0.16	
Cooler/condenser heating surface area, *m²*	265.	250.	170.	685.
Cooler/condenser weight, *t*	2.12	2	1.36	5.48
Cooler/condenser diameter, *m*	0.36	0.22	0.17	
Cooler/condenser length, *m*	4.63	4.6	4.4	
Methanol production, *kg/s*	1.16	0.55	0.28	1.99
Steam production at pressure of 4.3 MPa, *kg/s*	1.29	0.49	0.22	2

Table 3. Power unit equipment specification

Name	Unit	Value
Gas temperature upstream of the expansion gas turbine	*K*	303.15
Gas pressure upstream of the expansion gas turbine	*MPa*	7.86
Gas pressure downstream of the expansion gas turbine	*MPa*	0.96
Gas temperature downstream of the expansion gas turbine	*K*	202.2
Gas temperature upstream of the main gas turbine	*K*	1373
Gas pressure downstream of the main gas turbine	*MPa*	0.114
Gas temperature downstream of the main gas turbine	*K*	923
Main steam temperature of the steam turbine	*K*	781.2
Main steam pressure of the steam turbine	*MPa*	4.2
Main steam consumption by the steam turbine	*kg/s*	5.6
Low-pressure separator drum pressure	*MPa*	1.4
Steam flow from the low-pressure separator drum	*kg/s*	1.1
Low-pressure economizer heating surface area	m^2	201
Low pressure economizer piping weight	*t*	5.4
Low pressure vaporizer heating surface area	m^2	971
Low-pressure vaporizer piping weight	*t*	33.6
High pressure economizer heating surface area	m^2	297
High-pressure economizer piping weight	*t*	8
High-pressure evaporator heating surface area	m^2	296
High-pressure vaporizer piping weight	*t*	10.2
Steam superheater heating surface area	m^2	222
Steam superheater piping weight	*t*	7.9
Exhaust gases temperature	*K*	413
Exhaust gases volume	nm^2/s	33.7
Harmful emissions weight: ash sulphur oxides nitrogen oxides	*t/year*	 1.77 0.16 25.1

Table 4 shows the general technical and economic performance indicators of the ICPME. When determining these indicators, the price of methanol was assumed to be 550 USD/tce, and the electricity price was assumed to be 8 cents per kWh, which corresponds to the cost in power-hungry regions of the Far East [18, 38-40].

6 The discussion of the results

As it follows from the calculations performed, methanol and electricity production on the basis of the UCG gas is possible only if the high cost of electricity and liquid fuel in the area under consideration is combined with a sufficiently low cost of gas produced as a result of underground coal gasification.

Table 4. Technical and economic performance indicators of the ICPME

Name	Unit	Value
Annual methanol production	*t*	60087
Annual power supply to external consumers	*mln. kW*	50.1
Annual gas consumption of underground coal gasification	*tce*	77253
Methanol synthesis unit capital costs	*mln. USD*	28.4
Power unit capital expenditures	*mln. USD*	39.2
Total capital costs required by the ICPME	*mln. USD*	67.6
Number of employees	*persons*	80
Annual payroll	*mln. USD*	1.2
Depreciation charges	*%*	3.5
Allowance for running and major repairs	*%*	4.5
Cost of methanol produced	*mln. USD*	23
Cost of electricity produced	*mln. USD*	4
Cost of UCG gas required to ensure: IRR=15% IRR=20% IRR=25%	*USD/tce*	 124 75 52

A mathematical model of ICPME based on gas from underground coal gasification of the Rakovskoye deposit in the Far East, which is effective from the point of view of the adequacy of the presentation of the processes under study, has been developed.

The technical and economic optimization of the parameters was carried out on the basis of the model. The optimal ICPME parameters are found. The conditions for the competitiveness of the studied installations are estimated. The main findings of the study are as follows.

For the synthesis of methanol, unconventional once-through reactors were used with intermediate cooling of synthesis gas between the catalyst beds with steam to produce low pressure steam. This allows the use of synthesis gas with a low (compared to stoichiometric) H_2/CO ratio and eliminates the expensive CO conversion system in the synthesis unit. In this regard, the combined production of methanol and electricity increases thermal efficiency and reduces the specific capital investment in the plant.

An important feature of the combined processes is their environmental friendliness, which is due to the high requirements for the purity of synthesis gas from the synthesis catalysts and low NO_x emissions due to the small volumes of purge gases burnt in the gas turbine combustion chamber.

The sensitivity of the ICPME to changes in external conditions (cost of UCG gas) was investigated. Based on the analysis of the cost of diesel fuel in the eastern regions of Russia, it was concluded that even at present, methanol produced at ICPME is competitive with the expensive diesel fuel supplied. The introduction of such systems is economically feasible in the near future.

Thus, the ICPME presented here have a competitive environment. Practical implementation requires pre-design studies: increasing the stability of the gasification process, improving synthesis catalysts, parameters of a gas turbine, gas generators, etc.

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